

Lab 9 - El Niño

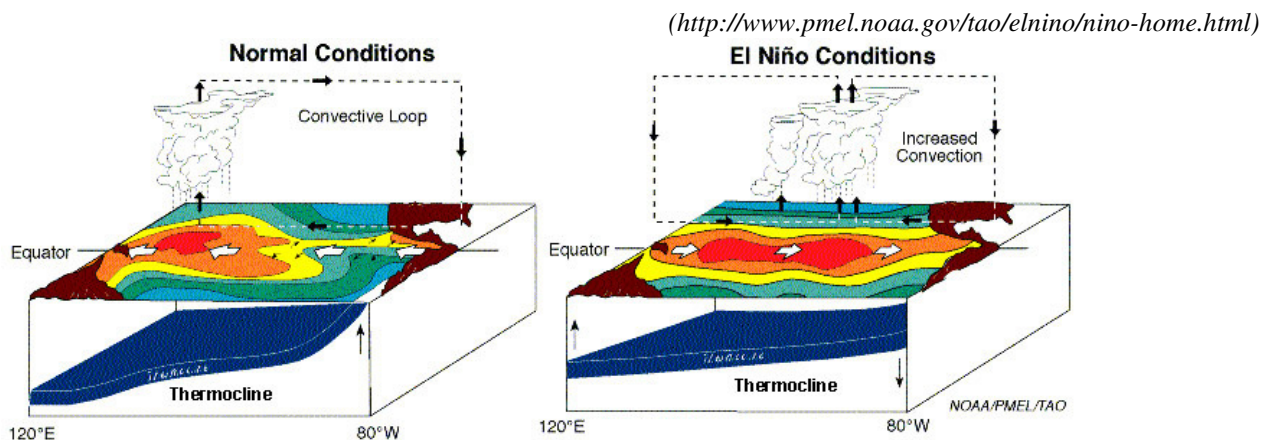
El Niño is probably one of the most widely publicized oceanic phenomena. If there's one single reason for that it's probably the fact that El Niño's presence can be quite catastrophic. During this lab, we will explore the phenomenon of El Niño, which of the ocean and the weather conditions relate to it, how it begins and how it ends. We will also look at the current conditions and see if we can predict with what we know whether there is an El Niño coming (or going).

What is El Niño

The term **El Niño** was originally used to describe unusual seawater temperatures in the Eastern Pacific by Peruvian fishermen. These people named the arrival of warm waters so because it would coincide in their calendar year with the Christian celebration of the birth of Jesus. Over the years we have come to realize that this event is affecting a much greater region than previously thought. So, today El Niño commonly refers to unusual oceanic conditions in the central and eastern equatorial Pacific. And, as with many oceanic patterns, what drives this phenomenon is changes in the atmospheric circulation. So, to understand and appreciate the importance of El Niño, we have to first observe and understand the normal conditions of both climate and ocean in this region of the world.

The Southern Oscillation

During normal conditions, **winds in the equatorial Pacific travel from east to west** (this is what the general atmospheric circulation predicts!). The direction to which the winds blow is further enhanced by the atmospheric systems in the area: **an atmospheric high in the eastern Pacific and an atmospheric low in southeast Asia** (see the diagram below). As these winds travel over the warm equatorial waters, they pick up moisture and heat, and eventually rise. Most of the moisture they have picked up, condenses and falls as precipitation in the western Pacific, while cooler, dryer air descends at the high. This pattern (east: high – west: low) is reversed every few years for some reasons not well known yet. During this reversal, the eastern and central equatorial Pacific experiences an atmospheric low with lots of rainfall, and southeast Asia and Oceania experience an atmospheric high with severe droughts. This see-saw between the two opposing high-low patterns of pressure systems has come to be known the **Southern Oscillation**.

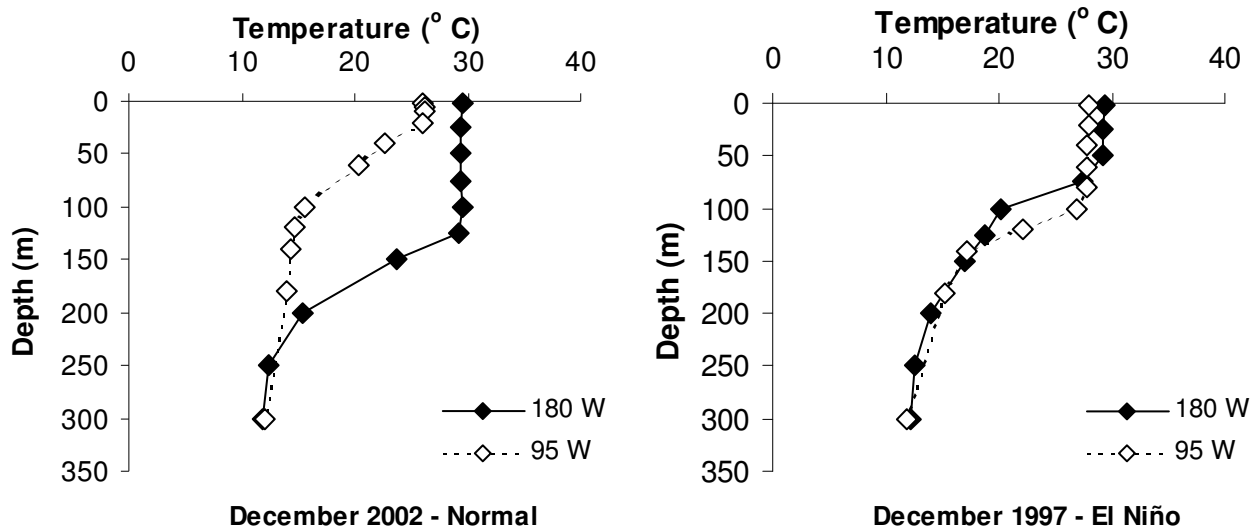


So, when the pressure is high in the east and low in the west (normal conditions), the direction of the resulting winds “agrees” with that of the general atmospheric circulations. During the unusual conditions, however, they are different. The result is that **the usual east-to-west winds are quite**

weakened! We now know that the event that actually triggers a response on behalf of the ocean (see below) is wind outbursts from Asia during this period of reversal in atmospheric conditions.

The implications on oceanic circulation: El Niño

Some of you may have already noticed the difference in the **thermocline** between normal and unusual conditions (in the diagram above). As the winds blow in the normal direction (east to west), the warm surface waters are piled in the western Pacific. These easterly winds along with coastal winds from the South American continent create a “gap” in the surface of the eastern Pacific. This “gap” is filled by deeper, colder water rising to the surface; this is described as **upwelling**. Overall, then, **the temperatures of the surface waters are higher and the thermocline extends deeper in the west than in the east ... during normal conditions** (see the left graph below).



(data courtesy of PMEL/NOAA)

Now, when the easterly winds are weakened due to the reversal in atmospheric pressure centers, the warm waters previously piled up in the western Pacific **surge back to the east**. This **raises the temperature of surface waters and deepens the thermocline in the eastern Pacific**, whereas the thermocline in the western Pacific becomes shallower (see the right graph above for the December 1997-98 El Niño)

El Niño-Southern Oscillation

In the previous two sections we see how the atmospheric patterns affect the ocean circulation. The surface ocean in turn can affect the atmosphere too. One good example of that is behind the reason for the unusual rainfall in the central and eastern Pacific during El Niño years. At that time, the winds don't move over cold, upwelled water; they move over warm waters surging back from the west! The winds become warmer and more humid, rise, and release the water that they picked up as heavy rainfall! So, there is a strong **feedback** between atmosphere and ocean, and that is the reason why oceanographers refer to this phenomenon as **El Niño-Southern Oscillation (ENSO)**, referring to both the atmospheric and oceanic processes contributing to it (also see the glossary at the end of this reading).

How does it end, then, if the interaction between ocean and atmosphere keeps perpetuating the conditions? It turns out that the ocean is more sluggish in its reaction to the atmospheric conditions than one would think. This means that a certain portion of the water mass still remains under the influence of the easterly winds even after these winds are weakened. This cold water mass travels as a wave to the western Pacific, bounces against the continental masses there and returns to the central Pacific. There, it **cools down the surface waters by raising the thermocline and interrupts the warming of the air**, thus breaking the feedback. This actually commonly results in unusually cold waters in the central Pacific. Scientists named this phenomenon **La Niña** as an “opposite” to El Niño.

The whole cycle from one El Niño event to another could take between two and eight years. Also, some events are much more intense than others and make their presence felt over a much greater area for a longer time. The most dramatic El Niño event of the last century was the 1997-98 event, and before that the previous intense event was the 1982-83 El Niño. Between these two, there was a mild event in 1986-87, and a mild but very long event between the years 1991-1995!

The impacts of El Niño

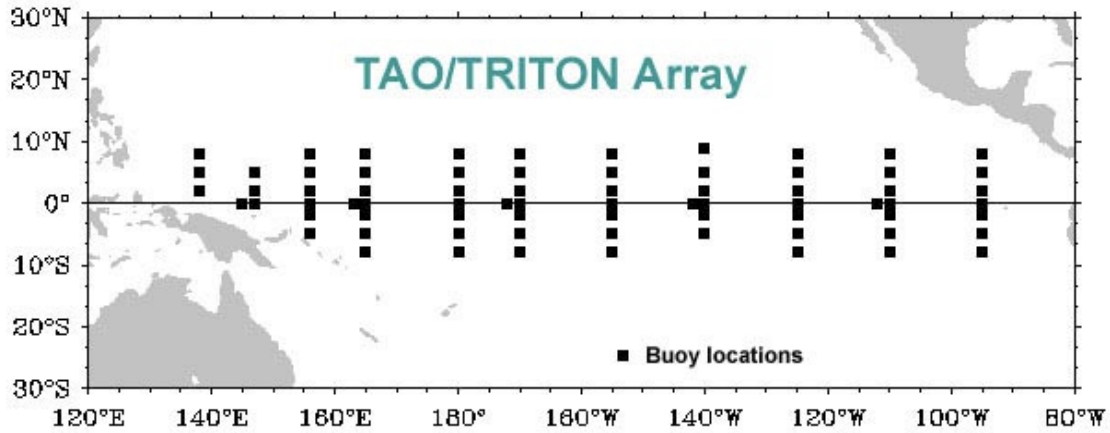
Probably most of the effects of El Niño you heard of in the media are detrimental and result in loss of millions of dollars. That is not wrong, but it certainly is not the full story. For example: upwelling brings cold water, rich in nutrients from the deep ocean to the surface, and this supports the large fisheries of the eastern Pacific. It also supports the communities dependent on the fish populations, including humans and seabirds. When upwelling bring up warm, nutrient-poor water during an El Niño event, the fisheries collapse and this has quite adverse impacts on the seabird populations and fishing communities in these regions. However, the heavy rains falling inland may support higher agricultural production than during normal, dry years, or even agriculture of certain crops in areas where it would not be possible otherwise. Lake fisheries and estuarine production of shrimp also increase during El Niño years. With careful management the adverse effects of this switch in climate may be significantly ameliorated.

Predicting El Niño events

The attempts to adjust to the impacts of ENSO events render the prediction of an event necessary. Indeed, the scientific tools developed to collect the information necessary for this prediction are quite impressive! Forecasters rely on changes in **wind direction and intensity, sea surface height, and sea surface temperature** at different parts of the Pacific ocean to determine whether the whole system is shifting from one set of conditions to another.

Remote (from a distance) and on-site sensors are used to measure different parameters. For example:

- Satellite **Altimeters** such as **TOPEX/Poseidon** can measure sea level (or sea surface height) within 1-2 centimeters!
- **Along-Track Scanning Radiometers** carried by satellites can measure the temperature of the earth’s surface (including the ocean’s surface) within 0.3 of a degree Kelvin!
- The **TAO/Triton Array** is a set of over 70 buoys (!) deployed all around the tropical Pacific, constantly measuring a large number of parameters such as wind direction and intensity, rainfall, humidity, seawater temperatures at different depths, water currents etc.



Most of the data we will use in this laboratory have probably been collected from these instruments. You will notice that most of them will be presented as **anomalies**. An anomaly is a **deviation from the normal or the usual**. In the case of sea level, for example, if you are told that at a certain location the sea level anomaly is + 3 cm, this usually means that the sea level there is 3 cm higher than the average over the whole time sea level was monitored there. By looking at anomalies over an area large enough, one is able to tell whether the conditions are changing a certain way or not. Currently, an El Niño event may be forecasted 12 months in advance!

Supplementary glossary from UCAR
<http://www.esig.ucar.edu/elnino/glossary.html>

El Niño is a term originally used to describe the appearance of warm (surface) water from time to time in the eastern equatorial Pacific region along the coasts of Peru and Ecuador. It was once suggested that minor El Niño events occurred about every two to three years and major ones about every eight to 11 years. Today, scientists note that El Niño has a return period of four to five years. When an El Niño event occurs, it often lasts from 12 to 18 months.

La Niña refers to the appearance of colder-than-average sea surface temperatures (SSTs) in the central or eastern equatorial Pacific region (the opposite to conditions during El Niño). Many scientists do not like the use of the term and prefer to call it a cold event (described below).

A **warm event** refers to the anomalous warming of SSTs in the central and eastern equatorial Pacific. This term is being used to avoid confusion over the use of other terms like ENSO and El Niño. A warming in the regions mentioned is accompanied by a relative cooling in the western equatorial Pacific.

A **cold event** is one where the SSTs become anomalously colder compared to the long-term average for the central and eastern equatorial region. (It is the opposite of a warm event in that region.) It has been referred to in the past as anti-El Niño and, more recently, as La Niña. La Niña, however, unlike the restrictive view of El Niño, is applied to Pacific basinwide phenomena.

The **Southern Oscillation** is a see-saw of atmospheric mass (pressure) between the Pacific and Indo Australian areas. For example, when the pressure is low in the South Pacific high pressure cell and high over Indonesia and Australia, the Pacific trade winds weaken, upwelling of cool water on the Pacific equator and along the Peruvian coast weakens or stops, and SSTs increase in these areas where the upwelling weakens.

The **Southern Oscillation Index (SOI)** has been developed to monitor the Southern Oscillation using the difference between sea level pressures at Darwin, Australia, and Tahiti, although other stations have sometimes been used. Large negative values of the SOI indicate a warm event, and large positive values indicate a cold event (also referred to as La Niña). It is important to note that there is not a one to-one correspondence between the occurrence of Southern Oscillation events and El Niño events, using the spatially restrictive original definition of El Niño.

ENSO is the term currently used by scientists to describe the full range of the Southern Oscillation that includes both SST increases (a warming) as well as SST decreases (a cooling) when compared to a long-term average. It has sometimes been used by scientists to relate only to the broader view of El Niño or the warm events, the warming of SSTs in the central and eastern equatorial Pacific. The acronym, ENSO, is composed of El Niño-Southern Oscillation, where El Niño is the oceanic component and the Southern Oscillation is the atmospheric component of the phenomenon. The broader definition of El Niño has sometimes been used interchangeably with ENSO, because ENSO is less well known in the popular electronic and printed media.